UNEMPLOYMENT INSURANCE AND THE BUSINESS CYCLE

Laura Brown[1]
Department of Economics
University of Manitoba

lbrown@cc.UManitoba.ca

Christopher Ferrall
Department of Economics
Queen's University

ferrallc@post.queensu.ca

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Abstract:
An equilibrium model is developed to study the interaction of the business cycle, unemployment insurance, and the labor market for young men in Canada. The model combines optimal job offer, layoff, and recall decisions within a numerically solved and restricted Bayesian-Nash equilibrium. We consider the long-run implications of changes made to unemployment insurance in Canada during the 1990s. The changes lead to equilibrium increases in average rates of unemployment, layoffs, and recalls. Eliminating UI lowers the equilibrium unemployment rate and average observed earnings. UI policy affects the timing of cycles of endogenous outcomes relative to the productivity cycle.

JEL Classification: L2, D2, J3, C4

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1. INTRODUCTION

This paper develops an equilibrium model to study how the business cycle and unemployment insurance (UI) interact within the labor market. We use the model to study the impact of changes made to UI in Canada during the 1990s. Our starting point is the calibrated two-sided model of job creation and destruction in Mortensen and Pissarides (1994). In that model the surplus of a worker-firm match is subject to idiosyncratic and common shocks. Workers and firms have common knowledge about the current and expected future surplus of an existing match. The number of created jobs in a period is determined by a function of the numbers of unemployed job seekers and posted job vacancies. An existing match is destroyed when its surplus falls below an endogenous threshold, because the value of either the aggregate or idiosyncratic component jumps.

We attempt to account for some patterns in the labor market not accounted for in the Mortensen and Pissarides model. First, a person's current wage depends more strongly on the state of the cycle at the time the match was formed than the current state (Beaudry and Dinardo 1991). In Mortensen-Pissarides the surplus, and thereby the wage, of a continuing match is unrelated to the aggregate state when the match was formed. Instead it shifts with the aggregate state through on-going bargaining over the current surplus based on symmetric information. Asymmetric information within a worker-firm pair, which we model, may limit the scope for renegotiation of wages in response to the aggregate state. Second, not all matches created in a given aggregate state start with the same earnings, and new matches do not begin with earnings above all existing matches. In Mortensen and Pissarides all matches begin with the best possible productivity, making earnings on new matches equal to each other and at least as high as in existing matches. Third, some vacancies are filled by workers already employed. In Mortensen and Pissarides only unemployed workers search and each match begins with the highest value of the idiosyncratic shock. Thus earnings in each match created in a given period are equal and are no lower than in any existing match.[2]

We also incorporate three elements of the Canadian unemployment insurance system that interact with cyclical patterns in job creation and destruction.[3] First, eligibility for UI benefits and the potential length of insured unemployment spells depend on weeks of insured work accumulated by an individual. Second, the level of benefits depends on pre-unemployment earnings. Finally, there is imperfect experience rating in the Canadian UI system. Recent recipients of UI are required to work longer before becoming eligible for benefits again, but the payroll tax funding the system does not vary with the history of benefits paid out to workers losing jobs from a given firm. Partial experience rating creates an incentive for firms and workers to use temporary layoffs as part of an overall response to common and idiosyncratic shocks. In Mortensen-Pissarides all separations are permanent.

The Mortensen and Pissarides model lends itself to quantitative comparisons of labor market and wage-setting institutions (Mortensen and Pissarides 1999). It strikes a balance between analytical and numerical solutions by ensuring that the overall match creation probability is determined by the current aggregate state and a small number of macroeconomic indicators (in the simplest case, the current unemployment rate). When attempting to account for the data within the institutional context described above we are unable to maintain this balance. Instead we study a restricted Bayesian-Nash equilibrium computed using simulated paths of the economy. The equilibrium is restricted because workers and firms interact only through a limited set of endogenous probabilities or beliefs. We solve for equilibrium beliefs by iterating repeatedly between two tasks: solving the dynamic programming problems of workers and firms given their beliefs and simulating the resulting economy in order to adjust beliefs to be consistent with realized outcomes.

In the model, a firm can respond to a decline in productivity by laying off and then later attempting to recall its worker. Workers search both on and off the job and face state-dependent probabilities of layoff, recall, and job offers. The model unemployment insurance system directly alters the effects that layoffs, recalls, quits, and job offers have on workers. These direct effects capture the rules in the Canadian UI system, which relate future UI benefits and lengths of insured unemployment to past labor market outcomes. As discussed in more detail later, UI has little direct effect on firms. But in equilibrium, UI indirectly affects firms by altering their beliefs about worker decisions to quit, accept recalls, and accept new job offers. The combination of equilibrium beliefs and actions generate endogenous probabilities of match formation and destruction.

The model can generate plausible predictions for many labor market phenomenon, such as job-to-job transitions, temporary layoffs and recalls, quits into unemployment, and a non-degenerate distribution of earnings. We focus on labor market outcomes of young men because they experience a high degree of labor market turnover (Wolpin 1992). To set parameters of the model, we calibrate the aggregate productivity cycle to the Canadian economy, and we set the parameters of the UI system to match the system in place in Canada from 1981 to 1989. We fix time discount factors and choose the remaining parameters to yield simulated moments similar to those found in data on the labor market outcomes of young Canadian men. We are able to find reasonable parameters with which to perform policy experiments. Removing UI altogether leads to lower unemployment uniformly over the business cycle. In comparison to the baseline of the 1980s, changes to UI in Canada since 1990 are found to raise unemployment rates and to exacerbate the effect of a recession in the new simulated equilibrium. Rates of unemployment are higher under the new UI rules because there is more churning in the labor market. Higher rates of unemployment and lower earnings are accompanied by more layoffs and more recalls of laid-off workers.

These equilibrium responses are somewhat surprising since changes to Canadian UI in the 1990s were partially motivated by a sense that the system in place since 1971 had contributed to the gap between unemployment rates in the U.S. and Canada (for example Lemieux and MacLeod 2000). In response, a series of legislative changes reduced benefit rates and tightened eligibility rules. Within our model the unintended consequence of contracting the system in the particular way it was done in the 1990s made it easier in equilibrium for firms to find workers and to recall laid off workers. The shorter wait for an acceptable job makes entering unemployment less costly for workers, thereby making it easier for firms to lay them off for short periods than under the older UI rules. In data not used to calibrate the model we find some support for the prediction of greater incidence of temporary layoffs after the policy changes we study.

2. THE MODEL

2.1 The Labor Market

The labor market consists of a large number of *ex-ante* identical workers and *ex-ante* identical firms. The number of potential jobs in the labor market, filled and vacant, equals the number of workers. Each period, which corresponds to four weeks of real time, a percentage l^d of workers are replaced by new workers who are unemployed and have no employment experience. A proportion λ^d of *unfilled* jobs are then destroyed each period and replaced with new unfilled jobs that have no workers to recall.[4] All agents observe a common shock, s, which takes on three values, $s \in \{s_l, s_m, s_h\}$, and follows a known Markov process with transition probabilities $P_{ss'}$. A job's productivity (revenue) is made of up three components. Associated with each value of s is a component of revenue common to all jobs, π_s. We set $\pi_m = 0$ and $\pi_l = -\pi_h$, leaving one free value, π_h, the average level of productivity in the high state, which we choose as part of the moment-matching described in section 3. Productivity also includes a worker-firm match specific component M_k, drawn from a set of N_w values, $\{M_1, M_2, \ldots, M_{N_w}\}$. Each value occurs with probability $1/N_w$. The third component of productivity, ϵ_i, is job- and period-specific. It takes on one of N_ϵ values, $\{\epsilon_1, \epsilon_2, \ldots, \epsilon_{N_\epsilon}\}$. These values are spread evenly over the range $[-B, B]$, where $B > 0$ is chosen. They occur with an equal probability $1/N_\epsilon$. Each period workers and firms receive private information. Workers may receive a privately observed outside job offer, and only the firm observes ϵ_i.

The worker and firm share the match value, implying that the earnings corresponding to match M_k is

$$w_k \equiv \alpha M_k, \tag{1}$$

where the worker's share $\alpha \in [0, 1]$ is fixed.[5] Workers can capture the rent from their outside alternative only by accepting it, and firms avoid large negative shocks only by laying off workers. The distributions of earnings and match values depend on two parameters μ and σ:

$$w_k = w_{min} + \exp(\sigma \Phi^{-1}((k - 0.5)/N_w)) + \mu, \quad k = 1, 2, \ldots, N_w, \tag{2}$$

where Φ^{-1} denotes the inverse of the standard normal distribution function and w_{min} denotes earnings just ineligible for unemployment insurance under the Canadian UI rules. Profit in an active match equals total product minus earnings, which using (1) can be written as

$$\pi_s + \frac{1-\alpha}{\alpha} w_k + \epsilon_i. \tag{3}$$

There are $3 \times N_w \times N_\epsilon$ distinct values for firm profits. The match does not end when the worker separates from the firm, because the firm can attempt to recall the worker. Instead, the match ends when the job is vacant and either it is destroyed (exogenously) or the firm finds a new worker willing to form a new match.

Figure 1 shows the sequence of decisions and actions beginning in an arbitrary period, t. If a job is filled, production occurs and the worker is employed and paid. If the job is empty, no earnings are paid, the firm incurs no costs, and the job disappears with (exogenous) probability l^d.[6] After production is complete some workers leave the labor market and are replaced by an unemployed worker with no employment experience. Firms that employed exiting workers begin period $t + 1$ with a vacant job.

At the end of period t new workers and jobs appear, the new aggregate state s is revealed, and each firm observes its idiosyncratic shock, ϵ_i^{t+1}. A firm with a filled job decides whether or not to lay off its worker. A firm with a vacant job decides whether or not to recall the previous worker or whether to post an outside offer. Recall and layoff announcements go out and unemployed workers respond to recall offers. A firm whose recall fails or that did not issue a recall now posts offers if they planned to do so. A new firm decides whether to post offers or to leave the job vacant again until next period. A randomly selected worker receives each job offer and the worker-firm match value is revealed to both sides. After all offers have been made and either accepted or rejected, all workers inform their current employers whether they will quit or remain on the job for production in period $t+1$, which then begins and the within-period sequencing of events is repeated.

2.2 Beliefs

Workers and firms base their actions upon beliefs concerning the actions of other agents. We restrict these beliefs to be a finite set of probabilities specific to each aggregate state s. Workers form beliefs about whether firms will issue recalls (r), layoffs (l), job offers while unemployed (o), and outside job offers while on the job (j). We write the vector of worker beliefs about these events as:

$$\Lambda_w \equiv \left(\lambda_l^l, \lambda_m^l, \lambda_h^l, \lambda_l^r, \lambda_m^r, \lambda_h^r, \lambda_l^o, \lambda_m^o, \lambda_h^o, \lambda_l^j, \lambda_m^j, \lambda_h^j \right) \in [0,1]^{12}. \tag{4}$$

Firms form beliefs about whether workers will quit their job (q), accept recalls (r), and accept a new job offer (o):

$$\Lambda_f \equiv (l_l^q, l_m^q, l_h^q, l_l^r, l_m^r, l_h^r, l_l^o, l_m^o, l_h^o) \in [0,1]^9. \tag{5}$$

The vector of all beliefs $\Lambda \equiv (\Lambda_w, \Lambda_f)$ is an element of $\mathcal{C} \equiv [0,1]^{21}$.

2.3 Unemployment Insurance

The UI system captures many of the elements of UI in Canada. It includes a shorter entrance requirement for claimants who did not collect UI benefits in the previous year, duration of benefits that depends on the duration of the previous employment spell, a fixed replacement ratio, and minimum and maximum benefit levels. If currently employed, the duration of UI benefits for which one would be eligible upon becoming unemployed depends on the number of periods employed, p, and the number of periods since receiving UI, n. The minimum requirement is t_E periods for a new claimant ($n > 13$) and $t_E + t_{ER}$ periods of work for a repeater ($n \leq 13$). (A year equals 13 periods since a period corresponds to four weeks). Once a worker qualifies for UI she may receive t_R periods of regional extended benefits. A qualified worker employed for half a year or less receives one additional period of benefits for each period worked and one additional period for each two periods employed after that, up to a maximum duration T of one year. The potential duration of UI benefits at the beginning of a spell of unemployment is

$$(6) \qquad \begin{cases} 0 & \text{if } p < t_E \text{ or } (n \leq 13 \text{ and } p < t_E + t_{ER}) \\ p + t_R & \text{if } (p \geq t_E \text{ or } (n \leq 13 \text{ and } p < t_E + t_{ER})) \text{ and } p < T/2 \\ \min\{T/2 + p/2 + t_R, T\} & \text{otherwise.} \end{cases}$$

Once unemployed p tracks periods remaining until benefits are exhausted. The level of benefits depend on p and the index of the previous earnings k. The proportion τ of previous earnings is insured up to the maximum insurable amount $w_{\max}$, as long as earnings are above the minimum insurable $w_{\min}$. Therefore, UI benefits can be written

$$(7) \qquad b(k,p) = \begin{cases} 0 & \text{if } w_k < w_{\min} \text{ or } p = 0 \\ \tau w_k & \text{if } w_{\min} \leq w_k \leq w_{\max} \text{ and } p > 0 \\ \tau w_{\max} & \text{if } w_k > w_{\max} \text{ and } p > 0. \end{cases}$$

We allow the UI system to include a flat tax on earnings, although we do not impose a requirement that the system's budget be balanced, which is appropriate as the Canadian UI system runs both deficits and surpluses. Below we discuss how this tax is incorporated into the policy simulations.

2.4 Workers

The model of worker behavior is similar to the one estimated by Wolpin (1992). Workers maximize expected present value of income, discounted at rate β_w. While a worker is employed their income equals the current earnings w_k. While a worker is unemployed their income equals $c_w + b_k$ where c_w is the direct value of a period spent unemployed and b_k is the level of UI benefits the person is eligible to collect based on earnings in the previous job, w_k. While a previously employed worker is unemployed a recall offer from the previous job arrives each period with probability λ^r_s. The earnings attached to a recall equal the previous earnings the worker received on the job, because the match value M_k survives the layoff period. If the worker accepts a recall, she enters the next period employed at the same earnings as her previous employment. If she does not receive a recall, or receives a recall and rejects it, then an outside job offer arrives with probability λ_s^o and some match value $M_{k'}$. The worker can either accept or reject the offer. If no offer is accepted this period, the worker enters the next period unemployed. If the worker accepts an offer, she has made a new match, and enters the next period employed at the new earnings $w_{k'}$.

Employed workers expect to be laid off with probability λ_s^l each period and expect an outside job offer to arrive with probability λ_s^j.[7] Workers incur no cost when switching jobs and will take any outside job offer that is higher than current earnings or quit into unemployment.[8] A worker's state vector takes the form

$$\theta_{w1} = (m, k, p, n, s), \tag{8}$$

which introduces a new variable m that indicates whether the worker is currently employed ($m = 1$) or not ($m = 0$).

The value of periods entered unemployed ($m = 0$) and employed ($m = 1$) are, respectively,

$$\begin{aligned} V_w(0,k,p,n,s) =& c_w + b(k,p) \\ & + \beta_w(1-l^d) \sum_{s'=s_l}^{s_h} P_{ss'} \Big\{ \Big\{ (1-\lambda_{s'}^o)(1-\lambda_{s'}^r) V_w(0,k,p',n',s') \Big\} \\ & + \lambda_{s'}^o (1-\lambda_{s'}^r) \Big\{ \sum_{k'=1}^{N_w} P_{k'} \max\{V_w(0,k,p',n',s'), V_w(1,k',p',n',s')\} \Big\} \\ & + \lambda_{s'}^r \Big(\max\Big\{ V_w(1,k,1,n',s') \ , \ (1-\lambda_{s'}^o) V_w(0,k,p',n',s') \\ & \qquad + \lambda_{s'}^o \sum_{k'=1}^{N_w} P_{k'} \max\{V_w(0,k,p',n',s'), V_w(1,k',p',n',s')\} \Big\} \Big) \Big\}, \end{aligned} \tag{9}$$

$$\begin{aligned} V_w(1,k,p,n,s) =& w_k + \beta_w(1-l^d) \sum_{s'=s_l}^{s'=s_h} P_{ss'} \Big\{ (1-\lambda_{s'}^j)\lambda_{s'}^l V_w(0,k,p',n',s') \\ & + (1-\lambda_{s'}^j)(1-\lambda_{s'}^l) \Big\{ \max\{V_w(0,k,p',n',s'), V_w(1,k,p',n',s')\} \Big\} \\ & + \lambda_{s'}^j \lambda_{s'}^l \Big\{ \sum_{k'=1}^{N_W} P_{k'} \max\{V_w(0,k,p',n',s'), V_w(1,k',p',n',s')\} \Big\} \end{aligned} \tag{10}$$

$$+\lambda^j_{s'}(1-\lambda^l_{s'})\sum_{k'=1}^{N_W} P_{k'}\max\{V_w(1,k,p',n',s'),V_w(1,k',p',n',s'),V_w(0,k,p',n',s')\}\Big\}.$$

The optimal decision at each state can be summarized by a reservation earnings index $k^r = k^r(\theta_{w1})$, $r \in \{u, e\}$, and an indicator function $I^R = I^R(\theta_{w1})$. If $m = 0$, then $k^r = k^r_u$ equals the index of the lowest earnings offer w_k that the worker is willing to accept. If $m = 1$, $k^r = k^r_e$ equals the lowest earnings for which the worker is willing to stay employed; for $k < k^r$ the worker quits the current job into unemployment or takes a new job if an acceptable one arrives this period. The function I^R indicates whether a currently unemployed worker is willing to accept a recall offer from the previous employer ($I^R = 1$) or not ($I^R = 0$). The decision to accept or reject a recall offer is different from the decision to accept an outside offer as dictated by the timing of decisions in Figure 1. In particular, if a recall is accepted the worker cannot receive outside offers. This is consistent with the timing of decisions made by firms which we describe below. The transition functions for the state variables are defined in the Appendix.

2.5 Firms

The firm's problem is simpler to write down than the worker's problem because firms are not directly affected by the UI system.[9] If the firm's job is occupied at the beginning of the period, the firm can either lay off or retain the worker. Firms take as given a (state-contingent) probability l^q_s that a worker will quit a job before production begins. If the job is vacant at the beginning of the period, the firm can without cost attempt to recall the previous worker with perceived probability l^r_s that the offer will be accepted. If the offer is rejected or the firm has chosen to forgo recalling the previous worker, the firm can then choose to post an outside offer with cost $c_f \geq 0$. Firms believe that with probability l^o_s the contacted worker will find the offer acceptable. The state of the firm is described by the vector

$$\theta_{f1} = (m, h, k, i, s), \tag{11}$$

where m is the previous employment status of the job (1=filled, 0=vacant), h indicates whether the job is new ($h = 1$) or existing ($h = 0$), k is the index of the match value, and i is the index of the current firm-specific shock. The firm chooses a vector of three binary values $d = (d^l, d^r, d^o)$: to lay-off a currently employed worker ($d^l = 1$), to put out a recall to the last worker who held the job ($d^r = 1$) or to post an offer to outside workers ($d^o = 1$).

The one-period expected profit for an existing firm ($h = 0$) can be written using the elements of the state vector and the decision vector d:

$$
\begin{aligned}
v_f(m, 0, k, i, s, d) =& m\left(\pi_s + (1-\alpha) M_k + \epsilon_i\right)\left[(1 - l_s^q)(1 - d^l)\right] \\
&+(1-m)\left(\pi_s + (1-\alpha) M_k + \epsilon_i\right)\left[d^r l_s^r\right] \\
&+(1-m)\left(\pi_s + (1-\alpha)\mu/\alpha + \epsilon_i\right)\left[\left(d^r(1 - l_s^r) + (1-d^r)\right) l_s^o d^o\right] \\
&-(1-m) c_f\left[\left(d^r(1 - l_s^r) + (1-d^r)\right) d^o\right].
\end{aligned}
\tag{12}
$$

where μ/α is the expected value of worker-firm matches. The first line equals the expected profit associated with a job remaining filled. The second and third lines are expected revenue and the fourth is the expected cost associated with the decision to fill a vacant job. A destroyed job yields zero expected profit. A new job ($h = 1$ and $m = 0$) has expected value

$$
v_f(0, 1, k, i, s, d) = (\pi_s + (1-\alpha)\mu/\alpha + \epsilon_i)\left[l_s^o d^o\right] - c_f[d^o]. \tag{13}
$$

The first term is the expected revenue from posting an offer and the second term is the expected cost. In general, the value of a job is

$$
V_f(\theta_{f1}) = \max_d \quad v(\theta_{f1}, d) + \beta(1-\lambda^d) E[V_f(\theta'_{f1})|\theta_{f1}]. \tag{14}
$$

$\text{Prob}(\theta'_{f1}|\theta_{f1}, d)$ is the probability transition function for the states of a firm and is defined in the Appendix. We then write the expectation in (14) as

$$
\begin{aligned}
&E[V_f(\theta'_{f1})|\theta_{f1}, d] \\
&\quad = \sum_{m'=0}^{1} \sum_{h'=0}^{1} \sum_{k'=1}^{N_w} \sum_{i'=1}^{N_\epsilon} \sum_{s'=1}^{3} \text{Prob}(\theta'_{f1}|\theta_{f1}, d) V_f(\theta'_{f1}).
\end{aligned}
\tag{15}
$$

Optimal firm behavior can be summarized by three reservation values of ϵ: $\epsilon_l^r = \epsilon_l^r(\theta_{f1})$, $\epsilon_R^r = \epsilon_R^r(\theta_{f1})$, and $\epsilon_o^r = \epsilon_o^r(\theta_{f1})$. For $\epsilon_i < \epsilon_l^r$ the firm lays off a currently employed worker. Similarly, if the job is vacant, the firm attempts to recall the worker if $\epsilon_i \geq \epsilon_R^r$. If the recall is refused or not offered in the first place, then the firm issues an outside offer if $\epsilon_i \geq \epsilon_o^r$. There is no theoretical ordering of these reservation values.

2.6 Equilibrium

Equations (9)-(15) use compact notation that makes implicit the choices of workers and firms (through the appearance of max on the right-hand side of the value functions). To define equilibrium beliefs it is easier to use more general notation that makes choices and information more explicit. First, let x be an index of worker and firm type agents, $x \in [w, f]$. Then expand the state vectors introduced earlier to include realized job offers, layoffs, quits, etc:

$$\theta_w \equiv (\theta_{w2}; \theta_{w1}) = (k', j, r, l; m, k, p, n, s) \tag{16}$$

$$\theta_f \equiv (\theta_{f2}; \theta_{f1}) = (o, a, q; m, h, k, i, s). \tag{17}$$

The additional elements θ_{x2} are binary, except for k' which takes on values $0, 1, \ldots, N_w$. For example, $\theta_{w2} = (3, 1, 1, 0)$ would indicate that the worker received an earnings offer ($j = 1$) with index $k' = 3$ and was recalled by their previous firm ($r = 1$). These imply that the worker is currently unemployed ($m = 0$) and could not have received a lay-off notice in the same period ($l = 0$). Suppose that this worker chooses to accept the recall offer. The previous firm would then have additional states $(0, 1, 0)$. The offering firm would have additional states $(0, 0, 0)$ because the outside offer was rejected ($o = 0$), any recall offer must have been rejected ($r = 0$), and firms can only make outside offers when a quit cannot happen ($q = 0$). Because some decisions and information occur in sequence in Figure 1, the set of feasible actions at a state θ_w is tedious to define. For example, a firm's decision to make an outside offer cannot be a function of whether the offer is ultimately accepted or not (o); and a worker's decision to accept a recall offer cannot be a function of whether an outside offer is received.

For the purpose of defining equilibrium beliefs it is only required that at each state workers and firms choose among a set of discrete contingent actions denoted $D(\theta_x)$. Then, (9)-(15) can be rewritten

$$V_x(\theta_x|\Lambda_x) = \max_{d \in D(\theta_x)} v_x(d, \theta_x) \tag{18}$$

where $v_x(d, \theta_x)$ is the value of the action d given optimal decisions will be made in all future periods. Optimal decisions based on (18) are discrete and will change abruptly as beliefs change smoothly. The choice probabilities are smoothed using the logistic transformation of choice values:

$$P_\delta(d|\theta_x) \equiv \frac{e^{\left(v_x(d,\theta_x)-V_x(\theta_x)\right)/\delta}}{\sum_{\hat{d}\in D(\theta_x)} e^{\left(v_x(\hat{d},\theta_x)-V_x(\theta_x)\right)/\delta}}. \tag{19}$$

As $\delta \to 0$ the choice probabilities converge to the decision rules defined by reservation earnings and productivity levels. Otherwise, there is a non-zero probability that agents take any feasible decision at each given state.

The model economy is a matrix of workers and firms who observe their private states θ_x and make simultaneous unilateral decisions d_x with probability $P_\delta(d|\theta_x)$. The full state of a worker-firm pair wf,

$$\theta_{wf} \equiv (\theta_w, \theta_f) \tag{20}$$

determines the transition to the next state θ' up to the identity of new partners, $w'f'$. Let $f(\theta)$ denote a distribution over match states. The state transition functions in the Appendix, the smooth decision probabilities (19), and the sequence of actions in Figure 1 lead to a Markov transition for the match states, $P(\theta'|\theta;\Lambda)$. Decisions at each match state can also be mapped to a binary vector $\omega(\theta)$ that corresponds to the belief vector (4)-(5). For example, if a firm lays off the worker in the high state $(s = h)$ then $\omega(\theta) = (0, 0, 1, 0, 0, \ldots, 0)$. The average value of $\omega(\theta)$,

$$\Omega(f, \Lambda) = \sum_{s\in\{l,m,h\}} \sum_{\theta} \omega(\theta) f(\theta; \Lambda), \tag{21}$$

is used to define an equilibrium set of beliefs as a $\Lambda^\star$ that reproduces itself in $\Omega(f, \Lambda)$ at the stationary distribution of $P(\theta'|\theta;\Lambda)$.

Definition: A *δ belief equilibrium* **is a vector of beliefs $\Lambda^\star \in \mathcal{C}$ such that**

D1. $f^\star(\theta') = \sum_\theta P(\theta'|\theta;\Lambda^\star) f^\star(\theta)$ and

D2. $\Lambda^\star = \Omega(f^\star, \Lambda^\star)$

Proposition: *For $\delta > 0$ there exists a δ belief equilibrium $\Lambda^\star$ in the interior of $\mathcal{C}$.*

Proof:

P1. The state spaces and choice sets are finite, the payoffs are bounded, and the discount rates are strictly less than one for workers and firms. Therefore unique solutions for the value functions (18) exist for all belief vectors $\Lambda \in \mathcal{C}$. Because the objective in (18) is linear in Λ, the value functions are continuous in Λ.

P2. $P_\delta(d|\theta_x)$ is continuous in $v_x()$ and $V_x()$ for all $d \in D(\theta_x)$ and all θ_x. $P_\delta(d|\theta_x)$ is therefore a continuous function of Λ. Further, $0 < P_\delta(d|\theta_x) < 1$.

P3. For $\Lambda \in \mathcal{C}$, $\delta > 0$, $0 < l^d < 1$, and $0 < \lambda^d < 1$ the transition function $P(\theta'|\theta;\Lambda)$ is irreducible, so a unique distribution $f^\star(\theta)$ satisfying (D1) exists for all $\Lambda^\star$. This stationary distribution is the solution of a linear system which is continuous in $P_\delta(d|\theta_x)$, and so the stationary distribution is continuous in Λ at all θ.

P4. The function $\Omega^\star(\Lambda) \equiv \Omega^\star(f^\star(\theta;\Lambda), \Lambda)$ is a continuous mapping from $\mathcal{C}$ to the interior $\mathcal{C}$. Therefore a vector of beliefs in the interior of $\mathcal{C}$ satisfying (D2) exists.

The iterative procedure used to find equilibrium beliefs is described in the Appendix. Since the equilibrium is a fixed-point in 21 dimensions it is not feasible to explore for possible multiple equilibria. A limited number of experiments at the baseline economy (defined below) using different initial beliefs revealed no evidence of multiple equilibria.

3. PARAMETERS

3.1 The Business Cycle

The transition probabilities for the aggregate shocks are exogenous to the market equilibrium defined in the previous section. The values used throughout the analysis are reported in Table 1C. The mean duration of each state and the probability of movement between states is estimated using the autoregressive model suggested by Christiano (1991). Details of the calculations are provided in the Appendix.

Based on $P_{ss'}$ in Table 1 the vector of ergodic probabilities for the Canadian data is $(0.171, 0.657, 0.171)$, implying, for example, that the model economy is in the low state 17% of the time. If the economy is in an expansion or a recession, there is a 97.7% probability that it will remain in that state during the next period (month). If it does not remain in the same state, the economy moves to the middle state. If the economy is in the middle state there is a 98.8% chance that it will remain in that state the next period. If it does not remain in the middle state, it is equally likely that next period's state will be low or high.

3.2 Unemployment Insurance

The values chosen for the unemployment insurance parameters appearing in the dynamic programming problem for individuals are reported in Table 1D. They were chosen to match as closely as possible the Canadian UI system in place throughout the 1980's. This period is chosen for two reasons. The UI rules remained unchanged from 1980 to 1989, and this period includes a complete business cycle. (The 7.5% unemployment rate in 1980 is identical to the unemployment rate in 1989.) While there were no major changes to UI rules during the 1980s, the particular entrance requirements and benefit duration faced by workers during this period varied with the unemployment rate over time and across regions of the country. The parameters are based on the mean unemployment rate over this period of 9.4%.[10]

For instance, the entrance requirement in Canada where the unemployment rate was 9.4% is 10 weeks; in the model, the entrance requirement is $t_E = 3$ periods, or 12 weeks. The penalty for repeat users of UI was six weeks, in the model it is $t_{ER} = 2$ periods. Eligible workers were paid one week of benefits for each week worked up to 26 weeks, thereafter one week of benefits were paid for each two weeks worked. In the model, one period of benefits are paid for each period worked up to 6 periods, thereafter one period of benefits is earned for each two periods worked. Under a 9.4% unemployment rate, extended regional benefits lasted 24 weeks ($t_R = 6$ periods). In the 1980s the earnings replacement ratio, τ, was 60% of the previous wage up to the maximum insurable earnings. The minimum and maximum benefit levels depend on a nominal maximum insurable weekly earnings level adjusted each year. In 1986, the base year for calculating real wages, maximum insurable weekly earnings $w_{\max}$ were \$495. The minimum insurable earnings $w_{\min}$ were equal to $.20 w_{\max} = \$99$.

3.3 Chosen Parameters

Three parameter values were not chosen by fitting them to aggregate data, government policy, or to match the model's simulated equilibrium to data. Their values are reported in Table 1B. The firm discount rate was set to $\beta_f = 0.997$, and as a four-week discount rate this implies a 4% annual real interest rate. The worker discount rate is set to $\beta_w = 0.97$ on the presumption that low-skill workers face a higher cost of borrowing than firms. The departure rate of workers from this market is set to $l^d = 0.0083$, which implies a mean duration of 10 years in the market for low-skilled labor.

3.4 Fitted Parameters

The remaining parameters were set by matching the moments generated from simulating the equilibrium of the model to moments derived from data on the labor market for Canadian men aged 20 to 24. Computational constraints, discussed in the Appendix, kept us from truly matching the model's predictions to the chosen moments as well as possible. But this procedure did achieve its primary objective: it found values of the model's parameters that would yield simulations similar to Canadian labor market outcomes. We choose to match the model to data on young males for three reasons. First, the business cycle is taken as exogenous, so our model is best thought of as a partial equilibrium model of one segment of the labor market. General equilibrium changes in UI policy would induce a response in the aggregate shocks, which we hold fixed throughout the policy experiments. Second, young men typically have relatively high rates of unemployment and receipt of UI benefits. Third, excluding young women avoids modelling the effect of maternity on reservation wages and decisions to quit jobs. (The Canadian UI system has a maternity leave component.)

The parameters varied to match the empirical moments are the absolute value of the aggregate shock (π_h), the vacant job destruction rate (l^d), the firm's cost of hiring a new worker (c_f), the worker's value of being unemployed for one period (c_w), the worker share of the match value (α), the mean (μ) and standard deviation (σ) of wage offers, and the absolute value of the largest idiosyncratic productivity shock (B). The moments chosen to match are the means and standard deviations of the unemployment rate, the proportion of people receiving UI within a period, and mean wages. The Appendix provides more details. By fitting these parameters to data on young men, but matching the business cycle to the overall economy, we allow that some of these parameters are specific to the market for the labor of young men. For example, explaining outcomes in demographic groups with higher earnings than young men might require different values of μ and σ. These differences might be rationalized by differences in skills across demographic groups, differences that are exogenous to the processes we study. We are also allowing that firms may experience different variances in both the idiosyncratic and aggregate shocks to the productivity of other types of workers. Again, this requires some difference in firm investments specific to workers in different groups that are unaffected by the endogenous outcomes within this model.

The parameters found by matching the simulated moments to the empirical moments are presented in Table 1. The worker's value of remaining unemployed c_w is low relative to the mean wages because workers obtain most of the benefit from unemployment through UI payments and through the higher probability of finding a job when unemployed than when working. On the other hand, the firm's cost of hiring a worker c_f is slightly greater than the mean wage in the labor market. The worker receives about 80% of the match value. Comparing B to π_h, we see the range of the idiosyncratic shocks is much larger than that of wages and aggregate shocks. The model requires a lot of volatility within the life of a match to create an incentive for firms to lay workers off. On the other hand, if the market experiences a good aggregate shock, there is a high probability that it will experience a good aggregate shock next period. Therefore, a smaller value of the aggregate shock will suffice to have an effect on firm actions.

3.5 Parameter Values for Policy Experiments

The equilibrium under the *Baseline* policy that held in Canada during the 1980s is compared to two other policies: the elimination of UI altogether (*NoUI*), and the rules introduced since 1990 (*NewUI*). The simplest way to eliminate UI benefits payments to workers in the model is to change the replacement rate to zero. This is done for the first simulation. However, UI does not only affect the economy in terms of benefits. It also affects taxes paid by firms and workers. To incorporate this feature into the model, elimination of UI must also eliminate taxes paid on wages into the UI Fund. Since payroll taxes are paid on wages, not match values, the share of the match retained by the firm now must be separated from the wages paid to the worker. Hence, profit under NoUI changes from (3) to

$$\pi_s + \frac{w_k}{\alpha} - (1+\zeta)w_k + \epsilon_i, \tag{22}$$

where ζ represents the tax rate on wages which is *removed* under the alternative simulation. In the base simulation, $\zeta = 0$, meaning the match value in the firm's profit function includes all taxes. In the alternative simulation, $\zeta = -0.04$, which approximates the total proportion of wages paid into the Canadian UI Fund by firms and workers from 1980 to early 1993.[11]

In 1990, 1993 and 1994 the Canadian government introduced a series of significant changes to the UI system.[12] For a geographical area similar to the case assumed for the base simulation, the entrance requirement rose from 10 weeks to 16 weeks. Regional extended benefits were reduced from 24 weeks to 20 weeks. The maximum duration of benefits was reduced from 49 weeks to 44 weeks, The replacement ratio fell to .50, and persons who quit or were fired with cause were disqualified completely. Finally, the changes increased the payroll tax rate by two percentage points.[13] Table 1D shows how these changes affect the model's UI policy parameters. [14]

4. POLICY SIMULATIONS

4.1 Equilibrium Outcomes

Tables 2 and 3 and Figure 2 summarize simulations of the equilibrium response to the three policy regimes described in the last section using the parameter values (in Table 1) found by matching the baseline case to empirical moments (in Table 2). First, the empirical moments and the moments simulated from the baseline policy show similar patterns across the cycle with some differences in the levels of the moments. The average unemployment rates are matched closely. The rate of UI receipt is somewhat lower in the baseline simulations and mean earnings somewhat higher. The standard deviation of the moments within business cycle states are higher in the data than in the baseline simulation.

The other columns of Table 2 show how the moments respond to policies. Not surprisingly, eliminating UI leads to a lower unemployment rate in all aggregate states. In each case unemployment drops to about 60% of the baseline levels. Another way to look at this change is to attribute a share of this 'excess' unemployment under the Baseline to each person that receives UI under the Baseline. By aggregate state (low to high) each UI month is associated with .73, .93, and .74 of another unemployment month, respectively. Weighted by the long run probabilities of each state, each UI month is associated with .86 more months of equilibrium unemployment above the NoUI equilibrium. Mean earnings also fall without UI, essentially because less productive match values are employed due to the incentive to work.

Somewhat surprisingly, unemployment rates go up in each aggregate state under the New UI rules. The changes in the rules essentially move the UI system towards NoUI 'on paper', but the labor market does not move unambiguously towards the NoUI equilibrium. There is only a slight drop in rates of UI receipt. Since the rules cut benefit eligibility and duration, this lack of response must come through the changed labor market equilibrium. In terms of excess unemployment the effect is more dramatic. For each UI month the New UI rules generate 1.31, 1.61, and 1.06 months of unemployment across the business cycle states. The long-run average is 1.46: each two people on UI can be thought of as generating a third unemployed person not receiving UI through the changes in firm and worker decisions generated by the UI policy. The New UI rules move mean earnings down, although the size of the change is small enough to be explained mainly by the increased payroll tax rate included in the New UI parameters.

4.2 Equilibrium Beliefs

Table 3 compares equilibrium beliefs held by workers (Λ) and firms (L) under each of the policies. First, consider the Baseline vectors. Some patterns are relatively straightforward. Layoff probabilities are counter-cyclical (indicated by a '$>$' below the vector). Quit, recall offer, and unemployed job offer probabilities are all pro-cyclical. Recall acceptances are counter-cyclical: laid off workers believe (rightly) that the probability of being recalled is higher during a recession than an expansion. And two vectors of beliefs are not monotonic across the cycle. On-the-job offer probabilities reach a minimum and offer acceptance probabilities reach a maximum in the middle state, not in one of the two extreme states. While the existence of three aggregate states adds a great deal to the computational burden, these non-monotonic effects in the equilibrium beliefs indicate that a two-state model can mask asymmetries between expansions and recessions that interact with the job matching process and the UI system.

Next, consider the equilibrium response of beliefs across the business cycle. Relative to the Baseline simulation there are twelve vectors of beliefs across states to compare. In only half of these vectors is the change in beliefs monotonic across business cycle (either zero or three ˆs in each block of probabilities). Most of these monotonic changes occur when eliminating UI altogether. This would result in lower layoff and quit probabilities and greater job offer probabilities while unemployed. Offers on-the-job are less likely, which is driven by the greater employment levels in all three aggregate states. Recall offers are also lower without UI, presumably because the lack of UI leads more layoffs to be ‘permanent’, i.e. less affected by the time-varying idiosyncratic shocks. Two belief vectors do not move in one direction upon eliminating UI. Firms believe it to be more likely that offers and recalls are accepted during recession but less likely in the middle and expansion states than in the Baseline.

The changes in beliefs induced by recent changes to the UI rules are not so straightforward and in several cases the opposite of those generated by removal of UI altogether. Recall from Table 2 that unemployment rates are higher under the (stricter) NewUI parameters than under the Baseline parameters. These changes lead to greater layoff and recall probabilities among workers. At the same time firms also expect workers to be more likely to accept recalls. Altogether, these changes indicate that tighter UI eligibility and lower benefits can lead to more short term layoffs based on the idiosyncratic shocks to revenue. Rather than discouraging use of the system, the changes can lead to more use.

The increase in temporary layoffs under NewUI reflects an interaction among firms, their currently attached workers, and unattached workers. For example, job offer probabilities are higher in recession despite the fact that there are more unemployed competing for offers in the NewUI equilibrium. In the other states outside offer probabilities go down. This pattern is a mirror reflection of the offer acceptance beliefs held by firms. They expect more offers to be accepted in expansions under NewUI (relative to the Baseline) but fewer in the other states.

Finally, note the changes in monotonicity (marked by ‘>’) across the business cycle across

UI policy regimes. Three belief vectors are monotonic in all three policies: layoffs, recalls, and recall acceptances. On-the-job offer probabilities are monotonic in none of the regimes. The remaining four beliefs exhibit different patterns across the policies. Perhaps the most interesting one is that job offer probabilities are pro-cyclical in the Baseline and NoUI but they reach a minimum in the middle state under the NewUI parameters. Again the business cycle and the UI system interact in a complex way.

4.3 Labor Market Aggregates

Figure 2 shows the simulated time path of selected variables under the three policy regimes. The graphs cover more than a full business cycle. During the simulations the duration of the aggregate states is equal to their average duration. The expansion ($s = h$) and recession ($s = l$) periods are shown along the x-axis in Figure 2A. It shows that the three policy regimes mainly affect the level of unemployment not its distribution over the cycle. Under the New UI rules the rate is nearly the same by the end of an (average) expansion as under the Baseline, but during middle states and recessions it is several percentage points higher. The pattern in mean duration of unemployment spells (below in Figure 2C) is more complex, since it is composed of both an incidence and a pure duration effect. At the beginning of an expansion mean duration goes up slightly in all three regimes, as the change in the aggregate state leads many firms to issue recalls, eliminating many layoffs due to idiosyncratic shocks. After that mean duration steadily falls as more and more workers take jobs, which arrive at a higher rate (Table 3). Since there are fewer vacant jobs there are fewer jobs totally destroyed, so fewer unemployed lose contact with their firms altogether. By the end of the average expansion the mean duration under NoUI is higher than in the other two regimes. When the economy goes into recession there is a short-term drop in duration as many firms respond with layoffs. Duration rises slowly under all three regimes. The peak in duration actually occurs when the economy moves back into the middle period, again generated by the recall of many short-term layoffs.

The pattern in mean earnings (2B) is similar. During an expansion mean earnings fall, in part because lower-valued matches are now viable. At the start of the recession there is a corresponding increase in mean earnings as low matches generate layoffs. This effect is not very pronounced under the Baseline and NoUI regimes, and during the recession mean earnings grow slowly. Under the New UI rules, however, mean earnings increase more sharply and thereby peak at the end of the recession.

The patterns in earnings and unemployment rates reflect, in part, a very complicated pattern in reservation earnings among the unemployed (Figure 2D). This in turn is determined by the interplay of equilibrium beliefs across states. First, note that the pattern for NoUI is very abrupt, because under NoUI workers are spread over only a few states (primarily the earnings of the previous match, which affects the value of a recall offer). Under NoUI reservation earnings go up during an expansion, driven primarily by the higher rate of job offers, making job search more productive. However, with a UI system in place reservation earnings fall quickly during an expansion. Job offer probabilities are very similar (Table 3), so this is caused by the unemployed wanting to get any job to establish a match and build up eligibility for UI while offers are available. This strategy is helped by the higher job offer rate during expansions and leads to the higher quit rate than under NoUI. These quits are mainly job-to-job transfers as employed workers can receive offers while holding a low-value match. During the recession reservation earnings increase under the Baseline and (particularly) the NewUI regime. This reflects the combined effects of UI eligibility and altered layoff and recall policies of firms. Unemployed workers are less likely to accept outside offers under the NewUI rules because they are receiving UI benefits and are expecting recalls. Both of these effects are missing in the NoUI case. What is surprising is that the Baseline equilibrium falls between the two. In effect, the modest reduction in UI eligibility creates a greater response by firms (in terms of layoff and recall decisions) to outweigh the worker reaction.

5. SUPPORTING EVIDENCE

In this section we present flows into unemployment among Canadian men aged 20-24 from the Monthly Labour Force Survey, 1976-2000. Let the number of employed and unemployed in month m be denoted E_m and U_m, respectively. Flows from employment to unemployment are classified into permanent layoffs, temporary layoffs, and quits, denoted L_m, T_m, and Q_m, respectively. The rate of unemployment and the rates of layoff and quitting are then:

$$
\begin{aligned}
u_m &= \frac{U_m}{U_m + E_m} \\
l_m &= \frac{L_{m+1} + T_{t+1}}{E_m} \qquad (23) \\
q_m &= \frac{Q_{m+1}}{E_m}.
\end{aligned}
$$

The empirical analogue to the equilibrium value of λ_s^l is an average value of l_m within a stage of the business cycle. The value q_m is not directly analogous to the equilibrium belief $l^q(s)$ because q_m only records employment to unemployment transitions, whereas in the model firms cannot distinguish those quits from job-to-job transitions. In fact, a very small number of quits in the simulated model are to unemployment. Figure 3 presents the movement of u_m, l_m, and q_m around their sample means on a logarithmic scale. Each series is smoothed using a cubic spline to dampen the seasonal pattern in labor market flows. Employment to unemployment flows are primarily layoffs, and layoffs vary more than quits over the business cycle.

As Mortensen and Pissarides (1994) emphasize, the layoff rate spikes near the beginning of high unemployment periods. Our model generates the same pattern with a meaningful distinction between layoffs and quits, because it includes private information between a worker and their firm and it excludes renegotiation of earnings once the match is formed. These elements would, all else constant, increase separations relative to a model without these frictions. Since the model was calibrated using only earnings and labor market stocks, it might be the case that it overpredicts employment to unemployment flows. Yet from Figure 3 we see that quits and layoffs average 13% over 1976-2000 but are uniformly less than 6% in the Baseline equilibrium (Table 3). Thus, if anything, young men experience more turnover and short-term job loss than the model generates. Although quits and layoffs are distinct events in the model, permanent and temporary layoffs are not. All layoffs are potentially temporary *ex ante*, but some become permanent *ex post*. The proportion of layoffs that are temporary depends on the recall offer and acceptance rates. Holding λ^l fixed, an increase in both of the recall rates would, to a first approximation, be associated with a greater share of layoffs being temporary. Thus, Figure 3 also displays the share of layoffs that are temporary:

$$t_m = \frac{T_{m+1}}{L_{m+1} + T_{t+1}}. \tag{24}$$

According to the Labour Force Survey about 10% of all layoffs are *ex ante* temporary and roughly 1% of young Canadian men are laid off temporarily each month. Temporary layoffs are less cyclical than permanent layoffs so that t_m falls sharply during the recession of the early 1980s and again in the early 1990s. The two post-recession patterns in Figure 3 differ from each other. Over the 1980s t_m rises slowly and the unemployment rate falls steadily. But in the 1990s t_m grew steadily as unemployment stayed high.

In the model the rates of unemployment, layoff **and** recall are uniformly higher in the NewUI equilibrium relative to the Baseline equilibrium. The unemployment rate among young Canadian men falls slowly during the 1990s. Layoff and quit rates fall steadily over this time, reaching new minimums two years before the unemployment rate. That the unemployment rate stays high during an expansion is consistent with a move toward the NewUI equilibrium. Short-term layoffs make up a growing share of layoffs during the 1990s, which is also consistent with a move toward the NewUI equilibrium. The short-run patterns must be interpreted with caution, because it is not feasible to compute the transition path from the equilibrium under one UI policy to another and because the expansion of the 1990s lasted longer than the average expansion in the model economy. Yet at least the flow data are consistent with the labor market for young Canadian men moving towards higher unemployment rates fuelled by more short-term layoffs and recalls, as predicted by the equilibrium analysis of the changes in the unemployment insurance system.

6. CONCLUSION

This paper uses an equilibrium model of a cyclical labor market to carry out experiments on the long run effects of unemployment insurance systems. The equilibrium analysis shows that changes in policy parameters can have unintended long run effects. In particular, we find that a certain tightening of eligibility requirements leads to greater unemployment and only a small drop in UI incidence in the simulated economy. Our results also indicate that the new UI rules in Canada incorporated in our model create excess amounts of unemployment in equilibrium: each month nearly three people are unemployed for every two people on UI that would not be unemployed without UI. This is a higher ratio than under the Baseline policy in which fewer than one unemployed person is generated for every UI case each month.

The business cycle aspect of our analysis appears important. The equilibrium under three policy regimes differ across the business cycle. For example, the New UI regime tends to exacerbate recessions more than the Baseline regime. These asymmetries are caused in part by dynamic aspects of UI rules, such as eligibility requirements and benefits that depend on past earnings. The unemployment rate in the sector we study, young men, remained high given the lengthy expansion during much of the 1990s. While this may be evidence that the policy change is having the predicted effect, we must stress the long-run nature of our predictions and the influence of other factors, such as smaller adjustments to the UI system made again in the late 1990s. Yet since the early 1990s the labor market for young men in Canada has displayed some patterns consistent with a shift toward the equilibrium response in our calibrated model to an analogue of actual UI policy changes. In particular, temporary layoffs and recalls made up a growing share of employment to unemployment transitions.

By pushing the limits of existing work in several dimensions, this paper leaves unaddressed some important questions and suffers from several limitations. Beliefs should depend on more than the current aggregate state. The model of earning determination should be less *ad hoc*. The procedure to choose parameters to fit the data should be more exhaustive, and the possibility of multiple equilibria should be explored. We have attempted to balance the precision in our parameter values, our equilibrium concept, and the richness of our model of a cyclical labor market subject to intricate policy interventions. All these concerns end up playing a role in the results, suggesting that future work should continue to push on each of these margins rather than focusing on some to the exclusion of others.

NOTES

1 This paper benefits from comments made by Audra Bowlus, Allen Head, and two referees, from discussions at "North American Labour Markets in Transition" held in Kingston, and from seminars at Aberdeen, Bergen, Leeds, Stirling, UC-San Diego, and Western Ontario. We gratefully acknowledge research support from the Social Science and Humanities Research Council of Canada.

2 Mortensen (1994) includes search by employed workers but retains the assumption that productivity begins at the highest value.

3 Recent equilibrium models of the design and effects of UI include Hansen and İmrohoroğlu (1992), Andolfatto and Gomme (1995), Hopenhayn and Nicolini (1997), Lyndquist and Sargent (1998), Marimom and Zilibotti (1999), and Hassler, et. al (1999).

4 All probabilities of actions taken by workers are denoted with ι. All probabilities of actions taken by firms are denoted with λ.

5 In a generalized Nash bargaining model of earnings and profits (such as the one estimated by Eckstein and Wolpin 1995), the worker and firm share the surplus value of the match not simply the current shared component of the match. Byrne (2001) incorporates a simple UI system into such a model.

6 The vacant job destruction rate is constant over the business cycle, but jobs are more likely to be empty during a recession which generates a cycle in the job destruction rates.

7 To capture differences in search intensity among unemployed and employed workers we assume that half of all job offers go to unemployed workers (given that they search harder), and half go to employed workers. Since there is a much larger number of employed workers than unemployed workers, employed workers will face a lower job offer probability than unemployed workers.

8 A job offer can go to a worker just laid off in the same period, and if it is accepted the worker makes a job-to-job transition with no intervening unemployment.

9 The model assumes zero experience rating of UI claims attributable to a firm, which is the case in Canada. This assumption can be relaxed to allow for experience rating, although it increases the length of the firm's belief vector.

10 The feedback between the unemployment rate and UI eligibility is an important element of the Canadian UI system (e.g. Milbourne et al. 1991). In our model this feature would require adding the unemployment rate in each aggregate state to the worker belief vector Λ.

11 The actual rate varied from 2.4% to over 6%.

12 Yet another a set of changes to UI was introduced in 1996. These changes were not include in this analysis.

13 The federal government originally introduced regional extended benefits as an add-on to UI payable out of federal coffers. The new extended benefits are payable by the UI Fund.

14 Disqualification of quitters is approximated by changing the transition function for p (benefits) for workers moving from employment to unemployment. To properly introduce disqualification would require a separate reservation wage for employed workers who are laid off and those who are not.

APPENDIX

1. Transition Functions

1.1 Workers

Under the Baseline

$$(A.1) m'_{m=0} = \begin{cases} 0 & \text{if } (1-r)(1-jk') & \text{[no offer or recall]} \\ & |j(k_u^r > k') & \text{[no recall, offer rejected]} \\ & |(1-jk')(1-r)(k_u^r > k) & \text{[no offer, recall wage rejected]} \\ & |rj(k_u^r > k')(k_u^r > k) & \text{[offer and recall rejected]} \\ 1 & \text{if } r(k_u^r < k) & \text{[recall accepted]} \\ & |(j+r)(k_u^r \leq k') & \text{[offer accepted]} \end{cases}$$

$$(A.2) m'_{m=1} = \begin{cases} 0 & \text{if } l(1-j) & \text{[layoff, no offer]} \\ & |lj(k_e^r > k') & \text{[layoff, offer rejected]} \\ & |(1-l)j(k_e^r > \max\{k,k'\}) & \text{[quit, offer rejected]} \\ 1 & \text{if } lj(k_e^r \leq k') & \text{[layoff, offer accepted]} \\ & |(1-l)(1-j) & \text{[no layoff, no offer]} \\ & |lj(k_e^r < \max\{k,k'\}) & \text{[either offer accepted]} \end{cases}$$

$$(A.3) \qquad k' = \begin{cases} k & \text{if } m(1-m') & \text{[leave job]} \\ & |mm'j(k \geq k') & \text{[offer rejected]} \\ & |mm'(1-j) & \text{[no offer]} \\ & |r(k_u^r < k) & \text{[recall accepted]} \\ k^o & \text{if } (1-m)j(k_u^r < k') & \text{[offer accepted]} \\ & |mm'j(k < k') & \text{[offer accepted]} \end{cases}$$

$$(A.4) \qquad p' = \begin{cases} 1 & \text{if } (1-m)m' & \text{[first month of work]} \\ p+1 & \text{if } mm'(p < T) & \text{[one more month]} \\ p-1 & \text{if } m(1-m')(p > 0) & \text{[one less month]} \\ 0 & \text{if } (1-m)(1-m')(p = 0) & \text{[no covered months]} \\ & |m(1-m')(p < t_E) & \\ & |m(1-m')(w_k < w_{min}) & \\ p + t_R & \text{if } m(1-m')(p \geq t_E) & \text{[regional suppl.]} \\ & |(n \leq 13)(p < t_E + t_{ER})(t < T/2)(w_k \geq w_{min}) & \\ \min\{T/2 + p/2 + t_R, T\} & \text{otherwise} & \end{cases}$$

$$(A.5) \qquad n' = \begin{cases} \min\{n+1, T\} & \text{if } (1-m)(1-m')(1-p) & \\ & |(1-m)m'|mm' & \\ T & \text{if } m'(p \geq t_{ER}) & \text{[qualifies as repeater]} \\ 0 & \text{if } (1-m')(p > 0) & \text{[receiving UI].} \end{cases}$$

Under NewUI

$$(A.6) \qquad p' = \begin{cases} 0 & \text{if } m(1-m')(1-l) \quad \text{[not laid off]} \\ & |m(1-m')(p < t_E) \\ & |m(1-m')(w_k < w_{min}) \\ \min\{T/2 + p/2 + t_R, T\} & \text{if } m(1-m')l(p \geq t_E)(w_k \geq w_{min}). \end{cases}$$

The first line accounts for the disqualification of quitters.

1.2 Firms

Employment Transitions

$$\text{Prob}(1,0,k|0,0,k,s,d) = (d^r l_s^r + (d^r(1-l_s^r) + 1 - d^r) l_s^o d^o \frac{1}{N_w})(1-l^d)$$

$$\text{Prob}(1,0,k' \neq k|0,0,k,s,d) = (d^r(1-l_s^r) + 1 - d^r) l_s^o d^o \sum_{k'<>k} P_{k'})(1-l^d)$$

$$\text{Prob}(0,1,k'|0,0,k,s,d) = l^d$$

$$\text{Prob}(0,0,k'|0,0,k,s,d) = 1 - \text{Prob}(1,h',k'|0,0,k,s,d) - l^d$$

$$\text{Prob}(1,k'|1,0,k,s,d) = (1-l_s^q)(1-d_s^l)(1-\lambda^d)$$

$$\text{Prob}(0,k'|1,0,k,s,d) = 1 - \text{Prob}(1,k'|1,k,s,d).$$

$$\text{Prob}(1,h'=0,k'|0,1,k,s,d) = d^o l_s^o$$

$$(A.7) \qquad \text{Prob}(0,h'=1,k'|0,1,k,s,d) = 1 - \text{Prob}(1,h'=0,k'|1,1,k,s,d).$$

Complete Transition Function

$$(A.8) \qquad \text{Prob}(m',h',k',i',s'|m,h,k,s,d) = \frac{1}{N_\epsilon} P_{ss'} \text{Prob}(m',h',k'|m,h,k,s,d).$$

2. Data Sources

All data are from monthly seasonally adjusted (MSA) series. The last date used is March 1993, since major changes to UI regulations came into effect April 1, 1993. Data on earnings of men 20 to 24 are not available in MSA series. To approximate the earnings available in a low skilled labor market, earnings in the service sector workers are used, deflated by the Consumer Price Index. The unemployment rate for males 20 to 24 is available from CanSim. UI regular benefit claimants are available for the 20 to 24 year age group, but not by sex. The UI claimant series for the model is calculated according to:

$$uir_m = uic_{bs}\frac{ue_m}{ue_{bs}lf_m} \tag{A.9}$$

where

uir_m = UI claimant rate for men 20 to 24

uic_{bs} = Number of UI claimants both sexes 20 to 24

ue_m = Number of unemployed men 20 to 24

ue_{bs} = Number of unemployed persons both sexes 20 to 24

lf_m = labor force, men 20 to 24

CanSim Data Series

VARIABLE NAME	SERIES NUMBER
Real GDP at Factor Cost	I37026
Consumer Price Index	P719500
Labor Force (both sexes, 20 - 24)	D774019
Labor Force (men, 20 - 24)	D774022
Number Unemployed (both sexes, 20 - 24)	D774036
Number Unemployed (men, 20 - 24)	D774039
Unemployment Rate (men, 20 - 24)	D774001
Unemployment Rate (both sexes, 15 +)	D767611
Number of UI Regular Claimants (20 - 24)	D730858
Earnings in Service Sector	L95674

3. Transition Function for s

The continuous state of the business cycle is measured using Canadian monthly real GDP (at factor cost), denoted y_t. (See the Appendix for the details and for all data sources.)

We let

$$y_t = \rho y_{t-1} + (1-\rho)\mu_y + e_t \tag{A.10}$$

where

$$e_t = \gamma e_{t-1} + v_t, \quad E v_t y_{t-1} = 0, \quad E v_t = 0, \quad E v_t^2 = \sigma_v^2 = \frac{z^2(1-\rho)}{\kappa} \tag{A.11}$$

Our estimate of ρ equals 0.977 and the kurtosis parameter κ is set to 3 as in the normal distribution. The variable z represents the size of the aggregate shock to the economy as a whole. It plays no role in calculating the transition matrix under the assumptions used in the current model. The elements of the Markov transition matrix $[P_{ss'}]$ can be found by solving the equations:

$$\begin{aligned} \rho &= 2P_{ll} + P_{lm} - 1 \\ \kappa &= 1 + 0.5\frac{P_{lm}}{P_{ml}}. \end{aligned} \tag{A.12}$$

4. Solution Method

Summary

- **S0.** Choose initial beliefs held by workers and firms about their labor market opportunities, $\Lambda^0 = (\Lambda_w^0, \Lambda_f^0)$, bounded away from 0 and 1.
- **S1.** At iteration $s \geq 0$, solve the worker and firm maximization problems by iterating on the respective value functions V_w and V_f give beliefs Λ^s.
- **S2.** Based on the optimal behavior of firms and workers, simulate the labor market over a large number of periods for a large number of workers and firms.
- **S3.** From the simulated data, calculate Ω^s defined in (21).
- **S4.** Set Λ^{s+1} to be a weighted average of Λ^s and Ω^s. Repeat S1-S4 until the vectors of new and initial beliefs converge.

S5. Calculate simulated moments at the equilibrium beliefs and the distance between simulated and empirical moments. Adjust the model parameters used to match the moments in order to reduce the distance.

Step 1

Both the worker and firm maximization problems are solved by backward iteration on their respective Bellman's equations. The solution is achieved when the equation for each possible state the worker/firm can reach is stationary; that is to say, the value of making a decision in a given state is independent of the time period. For each state attainable by the worker, the solution to the worker problem yields a vector of reservation earnings for both employed and unemployed workers, and an index which indicates whether an unemployed worker is willing to accept a recall to her previous job. For each state attainable by the firm, the solution to the firm problem yields a vector of yes/no decisions whether to post an offer for a newly created job, recall a previous worker for an existing vacant job, issue a recall and if refused post an outside offer for an existing vacant job, or layoff an employed worker.

Step 2

The simulated business cycle follows a deterministic pattern based on the expected duration of each phase of the cycle. Each worker and firm is given an identification (id) number to keep track of them throughout the simulation. For simplicity (and without loss of generality), the worker begins the simulation attached to a firm with the same id number. Workers can begin the simulation employed or unemployed, with or without unemployment insurance. Whether employed or not, workers are assigned an earnings index. This determines their earnings if employed and their unemployment insurance benefits if unemployed and qualified for unemployment insurance. The earnings index and employment status of the worker determines the initial earnings index and vacancy status (filled or empty) of the corresponding firm's job.

Both firms and workers enter *this period* in their final state from *last period*. All updating changes *this period*'s state. A worker or firm can be updated more than once if a worker refuses a recall and then accepts an outside job offer. Because only *last period*'s state is pertinent to all worker and firm decisions, only the *final* changes made to *this period*'s state carry forward into *next period*. Before *this period* ends, a percentage of firms with empty jobs are destroyed randomly with probability l^d and replaced by *new firms* with the same id numbers and vacant jobs. A percentage of workers also leaves the labor market and are replaced by new workers who are unemployed and have no prior work experience. When employed workers leave the labor market, the corresponding firm's final state from *last period* is changed from job filled to job empty.

Before *this period* begins, two lists are created based on *last period*'s final state: the id numbers of employed workers and the id numbers of unemployed workers. When outside job offers are posted, the offer is issued randomly to a worker on the list of employed workers with probability l^e. Before any action is taken *this period*, the decision vectors for the new firms are examined, and if the firm wishes to make an offer its id number is added to a list of such firms. If the firm does not wish to make an offer, it is updated as a potential new job for the *next period*.

Recall and layoff decisions for all firms are completed before any outside offers are issued. The element of each firm's decision vector that determines whether the firm wants to recall its worker is examined and the following events occur:

No recall: the firm's state for *this period* is updated. If the worker is still attached to this firm, her state is also updated as remaining unemployed.

Recall: If the worker's job id no longer matches this firm's id, then the worker cannot be contacted and the firm can decide to post an outside offer. If the firm's decision is not to post an offer the job remains unfilled until the beginning of *next period*. If the firm wants to post an outside offer its id is added to a list of such firms for *this period*. If the worker is still attached to this firm, her recall index determines whether or not she will accept the recall. If the recall is accepted, the worker returns to work at the previous earnings and the job is again filled. If the recall is rejected, the worker remains unemployed, and the firm's decision to post an outside offer is examined as if the worker had not been contacted.

For a filled job, the firm's decision vector indicates if the firm will layoff the worker. If yes, the firm is updated with the job now vacant, and the worker is updated as unemployed. If no, the worker's reservation earnings is examined to see if she will quit. If the firm does not layoff the worker and the worker does not quit, the firm is updated with the job remaining filled and the worker is updated as still employed. If the worker quits, the firm is updated with the job now vacant and the worker is updated as unemployed going into *next period*. Note, at this point, the worker's state ending *last period* and coming into this one is still employed. Therefore, the worker is still included in the list of *employed* workers available for job offers.

After all firms have completed their layoff and recall processes, the list of firms that wish to issue offers is processed. First, the decision whether to send the offer to an employed or unemployed person is determined randomly based on the proportion of offers destined for each group. A second random assignment determines to which worker on the appropriate list the job offer will be directed. The process to determine whether the offer is accepted or rejected depends on whether the worker is employed or unemployed.

If the worker is unemployed (from *last period*) but has already accepted a recall, then the worker's id is removed from the list and the new job offer is directed to another unemployed worker. Once the offer reaches a still-available worker, the worker's reservation earnings determines if she will accept the offer. If the worker accepts the offer she is updated as employed by the issuing firm and the firm is updated as employing the new worker. If the worker rejects the offer, the worker remains unemployed and the firm's job remains vacant going into *next period*.

If the worker is employed, it must be determined whether the worker has been laid off or not. If the worker has been laid off, the job is accepted if the offered earnings matches or exceeds the worker's reservation earnings. If the offer is accepted, the firm is updated with the job filled by the new worker and the worker is updated as employed by the new firm. If the worker has not been laid off, the job is accepted if the offered earnings exceed the worker's existing earnings. If the offer is accepted, the firm is updated with the job filled by the new worker; the worker is updated as employed by the new firm; and the worker's previous firm is updated as having its job vacant. If the offer is rejected, the firm is updated as having its job remain vacant. The worker at this point does not need to be updated, since her state was determined during the first round of firm decisions.

Finally, all workers who are unemployed and who did not receive offers or recalls are updated as remaining unemployed.

Step 3

For each simulated period, the recall, offer, on-the-job offer, and layoff probabilities facing the worker are calculated. The recall probability is calculated as the number of recalls issued, whether or not they reach the worker, divided by the number of unemployed workers. The offer probability is calculated as the number of offers issued to unemployed workers divided by the sum of the number of unemployed workers minus the number of unemployed workers who have accepted recalls *this period*. The on-the-job offer probability is the number of offers issued to employed workers divided by the number of employed workers. The layoff probability is the number of layoffs issued divided by the number of employed workers.

For each period, the probabilities for recall acceptances, job offer acceptances, and quits faced by firms are calculated. The probability that a recall is accepted equals the number of recalls accepted divided by the number of recalls issued, whether or not they reached the worker. The probability that an offer is accepted equals the number of offers accepted by both unemployed workers and employed workers divided by number offers issued. The probability that a worker quits a job equals the number of workers who quit their job, either to go into unemployment or to change job, divided by the number of employed workers.

At the end of each period, the vector of probabilities are assigned to the state of the economy in that period. These are averaged over all periods with the same state after discarding a number of periods to clear the effects of initial conditions.

Step 4

The beliefs are adjusted according to:

$$\Lambda^{s+1} = \Lambda^s + r_v(\Omega^s - \Lambda^s). \tag{A.13}$$

where $r_v \in (0,1]$ is the revision rate for the probabilities. Because the simulations are finite, the calculated probabilities are not continuous. Thus the belief vectors do not exhibit smooth convergence. Instead, they will continue to bounce around within some range that depends upon the size of the state spaces for workers and firms (which depend upon UI policies and other parameters) and the number of workers/firms in the simulation. When carrying out policy experiments (based on very large simulated economies) the iterations were simply run until none of the probabilities exhibited any trend over simulations. We ensured that at the end of the iterations the belief vectors had negligible variation (caused by the discreteness) compared to the difference in belief vectors across policies.

Step 5

The parameters in Table 1C other than $P_{ss'}$ where chosen to minimize the weighted sum of squared differences between simulated (SM) and empirical moments (EM). The moments chosen to match between the data and simulations of the model are the means ($l = 1$) and standard deviations ($l = 2$) of the unemployment rate ($v = 1$), the proportion of people receiving UI within a period ($v = 2$) and mean earnings ($v = 3$). Since there are three phases of the business cycle, there are $2 \times 3 \times 3 = 18$ moments. The distance between the moment vectors,

$$\sum_{s=l,m,h} \sum_{v=1}^{3} \sum_{l=1}^{2} w_{lv} (SM_{svl} - EM_{svl})^2 \tag{A.14}$$

was used as the objective while adjusting the parameters of the model.

The weights (w_{lv}) and moments are reported in Table 2. While changing the parameter values we set the size of the simulation small (in terms of the number of workers and firms and the number of discrete shocks) and the precision of the simulation loose (in terms of the convergence criteria for the belief vectors and the value functions). The values used in this stage are listed in Table 1A. The results reported are based on values after approximately one month of time on an IBM SP-2 parallel processing machine with eight nodes. Once this process was stopped the size and precision of the simulations was increased considerably, as indicated in Table 1A, for the precise calculation of beliefs under alternative policy regimes.

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TABLE 1.

BASELINE AND POLICY EXPERIMENT PARAMETERS

Panel A: Size and Precision of the Simulated Equilibrium

Symbol	Description	Mom.Match	Exper.
N_w	Number of wage offers	10	25
N_ε	Number of firm-specific shocks	10	25
	Number of people/firms in simulations	4000	80000
	Number of periods in simulations	2000	5000
	Number of initial periods ignored	400	500
	Tolerance on belief convergence	0.001	*
	Tolerance on value function converger	1E-05	1E-07

Panel B: Chosen (Fixed) Parameters

Symbol	Description	Value
β_w	worker discount factor	0.97
β_f	firm discount factor	0.997
λ_d	worker exit probability	0.0083

Panel C: Parameters Set to Match the Cdn. Business Cycle & Moments in Table 2.

Symbol	Description	Value
$P_{ss'}$	Aggregate state transition prob.	
	Low to Low	0.977
	Low to Medium	0.023
	Low to High	0
	Medium to Low	0.006
	Medium to Medium	0.988
	Medium to High	0.006
	High to Low	0
	High to Medium	0.023
	High to High	0.977
c_w	worker value of unemployment	10.906
μ	mean of log wages	6.285
σ	variance of log wages	0.634
c_f	firm cost of posting offer	2689.526
l_d	vacant job destruction prob.	0.126
α	worker share of match value	0.802
π_h	high state productivity	57.107
B	largest firm-specific shocks	9811.768

Panel D: Canadian Unemployment Insurance Parameters

Symbol	Description	Baseline	No UI	New UI
w_{min}	Mininum Insured Wage	400	-	400
τ	UI Replacement Rate	0.6	0	0.5
t_R	UI Regional Benefits	6	-	5
t_E	Regular Entrance Requirement	3	-	4
t_{ER}	Repeat UI Extra Entrance Req.	2	-	2
w_{max}	Maximum Insured Wages	1980	-	1980
ζ	Payroll tax rate	0	-0.04	0.02
T	maximum periods of UI receipt	13	-	12

* No specific tolerance was specified. Simulations were run until the beliefs were stationary

TABLE 2.

EMPIRICAL MOMENTS AND SIMULATED MOMENTS FROM BASELINE AND POLICY EXPERIMENTS

		Moment									
		Mean					Standard Deviation				
Variable	State	Weight	Empirical	Baseline	No UI	New UI	Weight	Empirical	Baseline	No UI	New UI
Unemployment Rate		3.00					1.00				
	low		0.20	0.22	0.16	0.25		0.020	0.009	0.011	0.007
	medium		0.14	0.17	0.11	0.20		0.028	0.012	0.010	0.015
	high		0.12	0.12	0.08	0.13		0.009	0.014	0.008	0.019
UI Receipt Rate		5.00					1.00				
	low		0.13	0.07	0	0.07		0.023	0.003	0	0.004
	medium		0.09	0.06	0	0.05		0.023	0.002	0	0.002
	high		0.09	0.05	0	0.05		0.014	0.005	0	0.004
Wages		2.00					1.00				
	low		1582.2	1666.0	1590.6	1658.4		8.67	2.63	2.94	9.37
	medium		1558.2	1659.6	1589.9	1644.0		14.74	4.21	8.75	9.37
	high		1547.4	1656.3	1579.5	1639.7		7.16	2.51	9.36	1.74

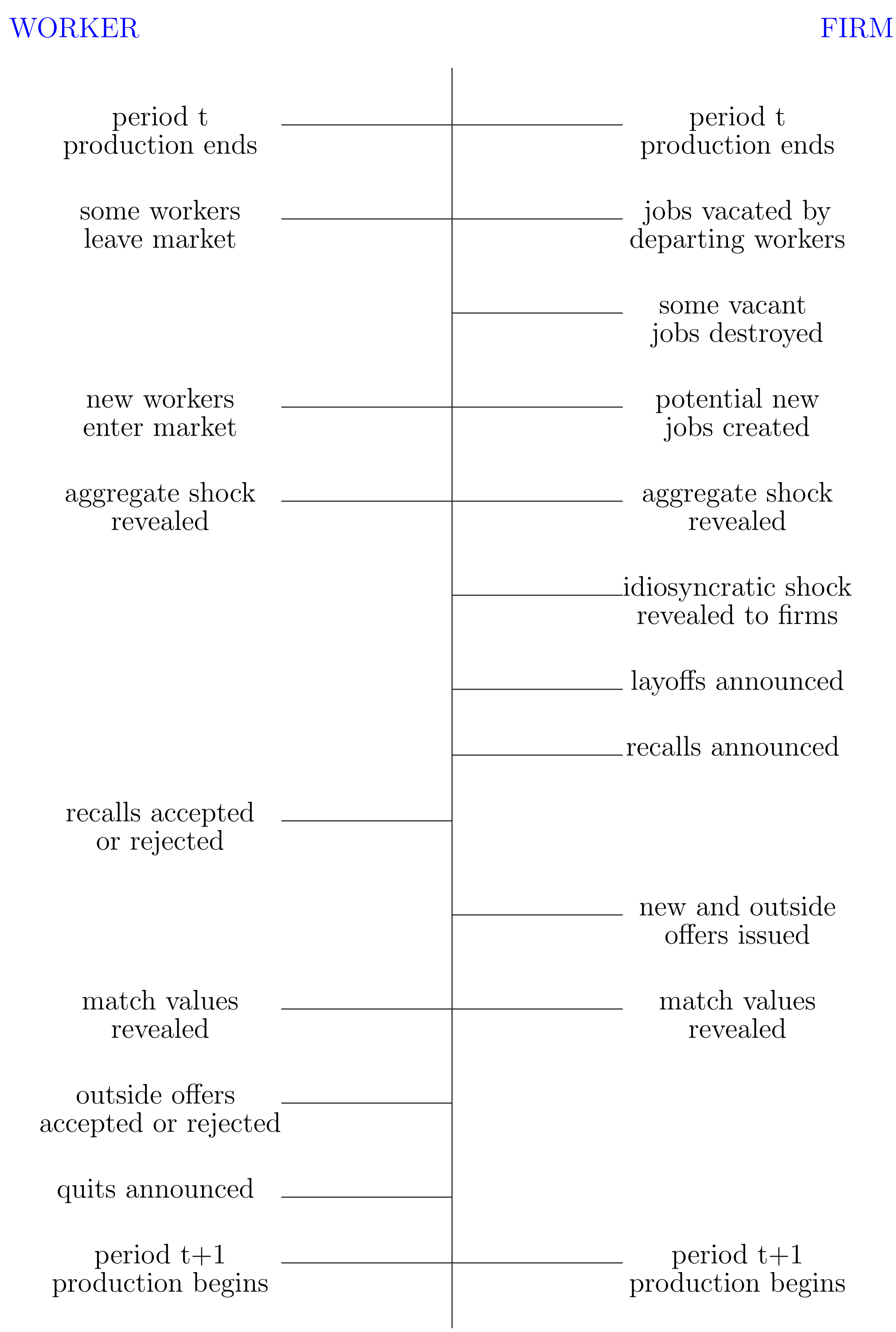
See Appendix 2 for data sources. Value of the objective at final parameter values: 5.94. See section III for details.

TABLE 3.
EQUILIBRIUM BELIEFS UNDER ALTERNATIVE UI POLICIES

		Λ Held by workers about firms								L Held by firms about workers					
		r-Recall		o-UE Offer		j-Emp Offer		l-Layoff		o-Acc Offer		r-Acc Recall		q-Quit	
Policy	State	Value	Δ	Value	Δ	Value	Δ	Value	Δ	Value	Δ	Value	Δ	Value	Δ
Baseline	low	0.208		0.123		0.030		0.057		0.418		0.272		0.003	
	medium	0.150		0.140		0.027		0.032		0.442		0.185		0.004	
	high	0.083		0.198		0.028		0.011		0.429		0.050		0.006	
	Δ	>		>				>				>		>	
No UI	low	0.194		0.130	^	0.021		0.047		0.447	^	0.318	^	0.0029	
	medium	0.062		0.178	^	0.022		0.015		0.406		0.124		0.0034	
	high	0.023		0.199	^	0.019		0.004		0.372		0.049		0.0031	
	Δ	>		>				>		>		>			
New UI	low	0.218	^	0.130	^	0.037	^	0.081	^	0.401		0.339	^	0.005	^
	medium	0.195	^	0.121		0.027		0.050	^	0.436		0.261	^	0.003	
	high	0.085	^	0.189		0.029	^	0.013	^	0.431	^	0.070	^	0.006	
	Δ	>						>				>			

^ indicates the probability to the left is higher than the corresponding value under the baseline policy.
> indicates that the vector of beliefs above are monotonic across the business cycle.

Figure 1. Sequencing of actions and events within a Period



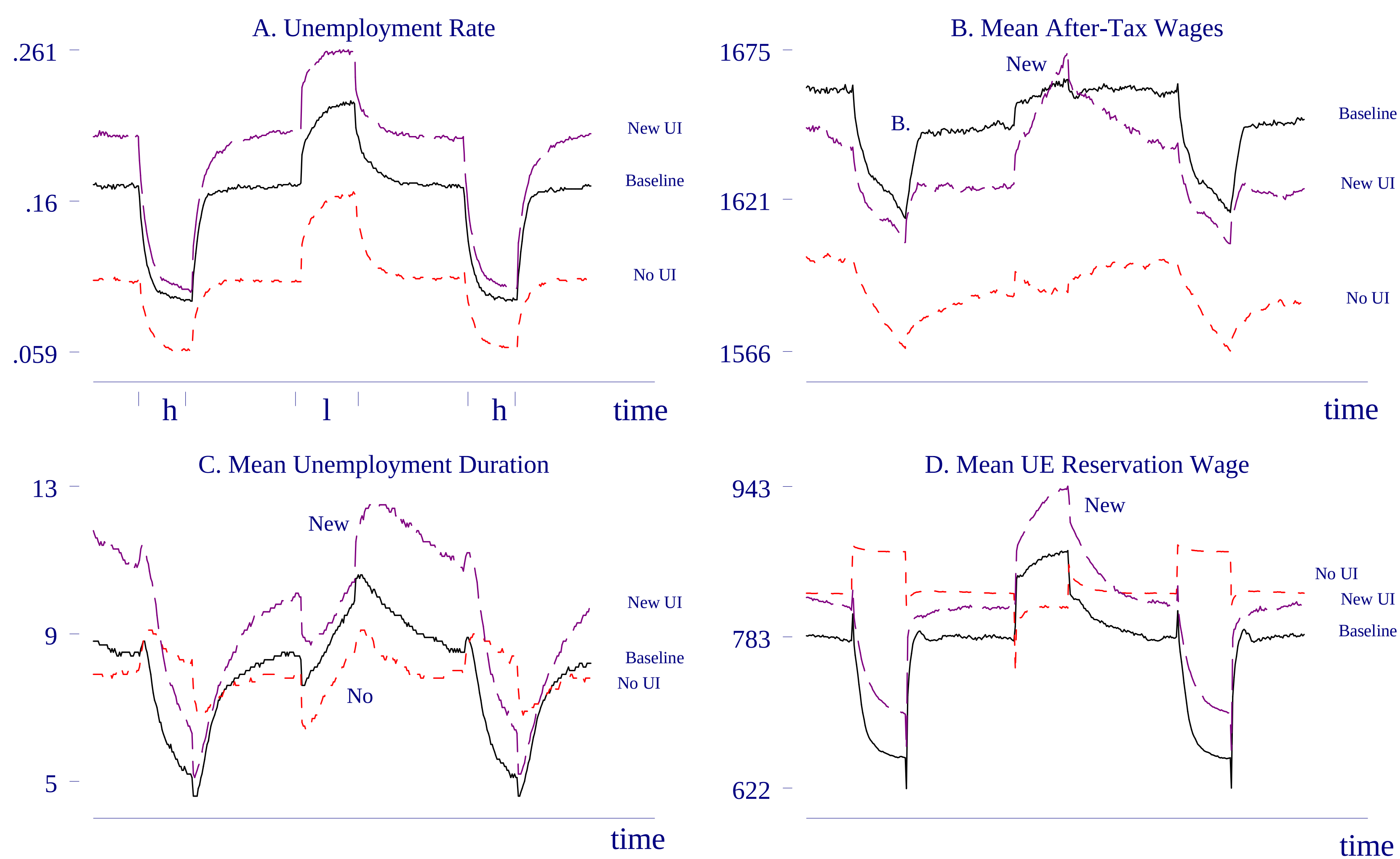


Figure 2. Simulated Time Paths of Selected Variables

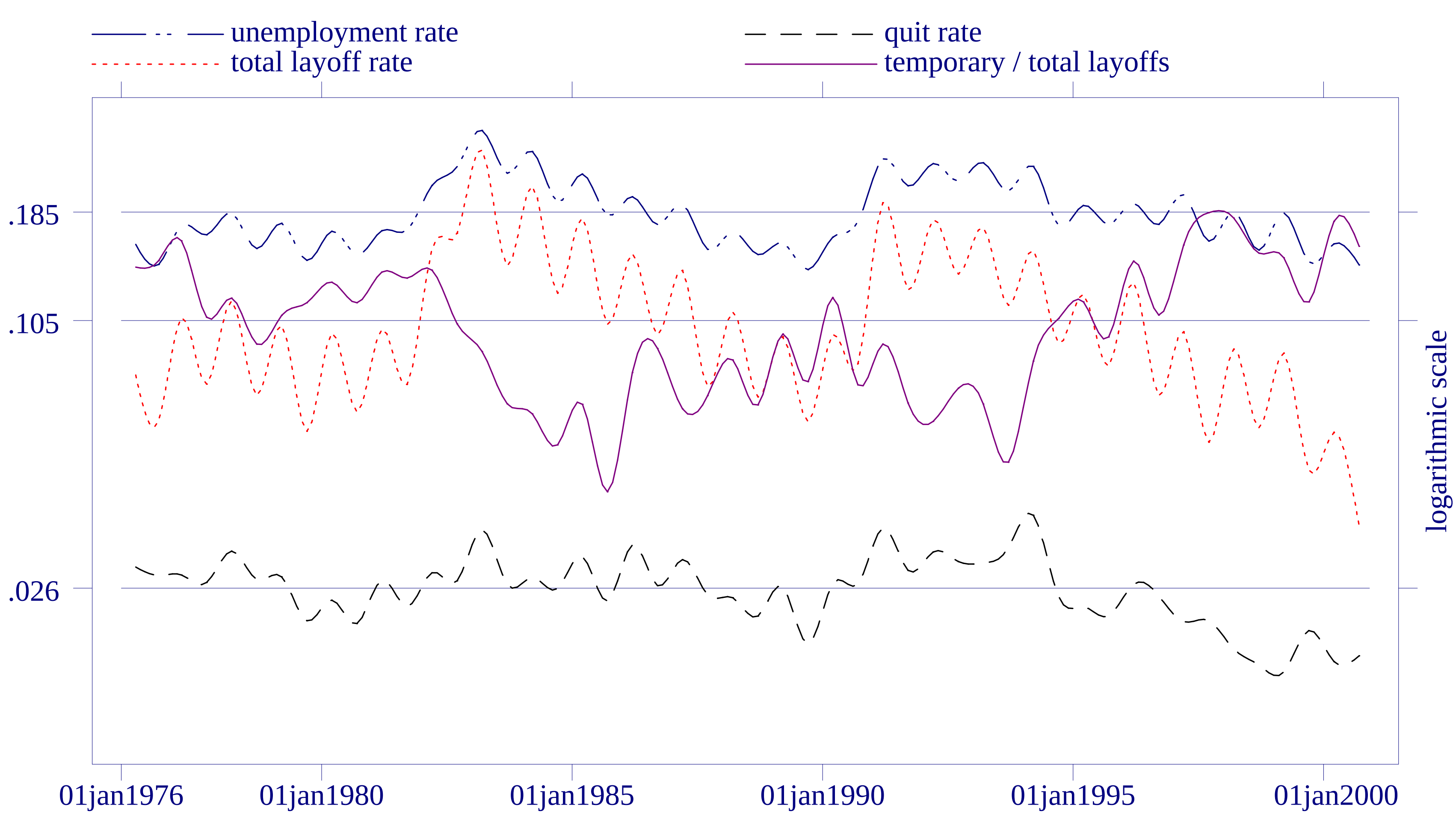


Figure 3. Unemployment, Layoffs, and Quits

Men Age 20-24, Canada 1976-2000